

of capital, and provides an accurate estimate of the implicit rental price for purposes of estimating TFP. This theory is based on a market equilibrium relationship between the price a firm is willing to pay to acquire an asset and the services that it provides over its lifetime. While theoretically correct, it is recognized that the implicit rental price formula can generate more volatility in rental prices than is found in observed rental prices. Therefore, we have sought to reduce the volatility in our rental price formula. Harper, Berndt, and Wood²² recently evaluated a variety of rental price equation formulations. One method they consider is to base the rental price equation on three-year moving averages of the cost of capital and capital gains, instead of their current values. The three-year moving average approach yields considerably more stable implicit rental prices than in our original study. We use the three-year moving average approach in the simplified method. Table 6 shows the impact on measured TFP growth of basing the rental price equation on three-year moving averages of the cost of capital and capital gains.

²² Michael J. Harper, Ernst R. Berndt, and David O. Wood, "Rates of Return and Capital Aggregation Using Alternative Rental Prices," in D.W. Jorgenson and R. Landau, eds., Technology and Capital Formation, (Cambridge MA: The MIT Press, 1989), pp. 331-372.

Table 6
Sensitivity Analysis:
Original Christensen LEC TFP Study Results Versus
Use of Three-Year Moving Average in Rental Price Equation
1984-1993

<u>Year</u>	<u>TFP Growth</u> <u>Original Study</u>	<u>TFP Growth</u> <u>Using Three-Year</u> <u>Moving Average</u>
1984		
1985	1.1%	1.2%
1986	2.8%	2.7%
1987	1.8%	1.8%
1988	2.1%	2.1%
1989	2.0%	2.0%
1990	4.6%	4.6%
1991	1.2%	1.3%
1992	3.5%	3.6%
1993	2.6%	2.6%
Average, 1984-93	2.4%	2.4%

Differences between the rental price equation in our original study and the rental price equation in the simplified TFP method do not have a significant impact on measured TFP growth. This is because changes in rental prices do not affect the quantities of capital input and only have a minor effect on the capital input weights in total input.

Issue 1g. What is the most reasonable method for developing a labor index for inclusion in a TFP calculation?

Economic theory holds that the quantity of labor input is related to the hours worked by LEC employees, weighted by their relative compensation levels. In our original TFP study we distinguished

management and non-management employees, because of their different levels of compensation. The quantity of labor input was constructed as a Tornqvist index of management and non-management employees, using their relative compensation levels as weights. This was the most detailed breakdown of employee hours and compensation that was available. Consequently it provided the most accurate measure possible of labor input.

Even this limited breakdown of hours and compensation required non-publicly-available data from various internal company records. In order to achieve the FCC's objective of basing the computations on accessible and verifiable data, the simplified TFP method bases its measure of labor input on the total number of employees, which is reported in the Form M. While changes in the total number of employees from year to year will not exactly match changes in hours worked or changes in the mix between management and non-management employees, it provides an attractive balance between accuracy and verifiability. Table 7 shows the impact on measured TFP growth of using the total number of employees as the measure of labor input.

Table 7
Sensitivity Analysis:
Original Christensen LEC TFP Study Results Versus
Use of Total Employees to Measure Labor Input
1984-1993

<u>Year</u>	<u>TFP Growth</u> <u>Original Study</u>	<u>TFP Growth</u> <u>Using Total Employees</u>
1984		
1985	1.1%	1.6%
1986	2.8%	2.1%
1987	1.8%	2.6%
1988	2.1%	3.0%
1989	2.0%	1.9%
1990	4.6%	4.1%
1991	1.2%	1.7%
1992	3.5%	2.9%
1993	2.6%	3.6%
Average, 1984-93	2.4%	2.6%

The FCC has also asked how post-retirement benefits will affect the measure of labor input. Post-retirement benefits affect labor compensation reported in the Form M/ARMIS 43-02, but it does not affect the number of employees, which is the basis for determining the quantity of labor input in the simplified TFP method. This means that the post-retirement benefits will slightly increase the labor's share of total input. Since the quantity of labor has been falling relative to the quantity of other inputs, this would mean that the inclusion of post-retirement benefits in labor's share of cost will slightly increase the rate of measured TFP growth.

Issue 1h. What is the most reasonable method for developing a materials index for inclusion in a TFP calculation?

In our original TFP study we used the Gross Domestic Product Price Index to reflect price trends for materials. This was done for two reasons. First, the ARMIS 43-02 Report, which was our public data source for materials expenditures, does not provide a breakdown of materials expenditures by type of good or service. Second, information was not available on prices paid by LECs for their materials. Because materials expenditures are diverse in nature, and because the GDPPI reflects overall inflation in the economy, it provides the most reasonable basis for developing a materials price index.

Because the GDPPI is the most reasonable basis for the materials price index, the simplified TFP method also uses the GDPPI to deflate materials expense.

Issue 1j. Is there a valid distinction between intrastate and interstate productivity for the purposes of calculating a TFP index and an input price index and, if so, does a satisfactory method exist to account for such differences?

There is no valid distinction between intrastate and interstate productivity or between intrastate and interstate input prices. This is because there is no economically valid distinction between intrastate and interstate inputs. Intrastate and interstate services have joint and common inputs and there is no economically meaningful allocation of these inputs

between jurisdictions: any allocation of these inputs between intrastate and interstate services is arbitrary. We make no attempt to arbitrarily measure interstate and intrastate TFP growth in either our original TFP study or the simplified TFP method.

Issue 1k. Is there a valid distinction between regulated and nonregulated productivity, or the productivity associated with specific services, such as video dialtone, or groups of services, for purposes of calculating a TFP index and an input price index? If so, does a satisfactory method exist to account for such differences?

TFP can be calculated for specific services or groups of services only if they do not share joint and common inputs with other services. Both our original TFP study and the simplified TFP method measures TFP for all services that have joint and common inputs with regulated services. Under Part 32 accounting rules, nonregulated services that have joint and common inputs with regulated services are included in operating revenue and operating expense. Hence those services were included in our TFP study. Nonregulated services that have no joint and common inputs with regulated services are not included in operating revenue or operating expense and were not included in our TFP study. Therefore the original TFP study and the simplified method correctly group services for purposes of measuring TFP growth.

The Simplified TFP Method

Because of the concerns raised by the FCC regarding the accessibility and verifiability of some of the data used in our original TFP study, we have developed a simplified TFP method that is based entirely on publicly-available data. A few additional modifications to our original study have also been made in the simplified TFP method, to address other concerns raised by the FCC. At the same time, the simplified TFP method is consistent with accepted productivity measurement practices and provides an accurate measure of productivity trends for LECs. Therefore, we believe the simplified TFP method maintains accuracy in measurement as well as a proper balance between precision in measurement and verifiability

We now summarize the differences between the methods and data sources in our original study and the methods and data sources in the simplified TFP study:

Output. The only way in which the measurement of output in the simplified model differs from the measurement of output in the original study is that the quantity of long distance service and the quantity of intrastate access service are derived by dividing booked revenue (as opposed to billed revenue), reported in the Form M, by the price indexes for long distance and intrastate access service.

Capital. There are five differences between the simplified model and the original TFP study regarding the measurement of capital. First, the simplified study uses the U.S. economy cost of capital implicit in the U.S. National Income and Product Accounts as the cost of capital in the rental price equation, instead of Moody's average yield on public utility bonds. Second, the simplified TFP method uses investment price indexes published by the U.S. Bureau of Economic Analysis instead of Telephone Plant Indexes. The BEA non-residential structures price index for telephone and telegraph structures is used for buildings and cable and wire. The BEA producer durable equipment price index for communications equipment is used for switching equipment, transmission equipment, and information origination/termination equipment. The price index for general support equipment is a Tornqvist index of four BEA producer durable price indexes: office, computing, and accounting machinery; furniture and fixtures; trucks, buses, and truck trailers; and non-residential producer durable equipment. The weights used in the Tornqvist price index are based on book value of investment in general purpose computers, furniture and office equipment, motor vehicles, and other general support equipment, reported in the Form M. Third, the simplified TFP method employs beginning-of-year 1988 book values of gross plant, reported in the Form M, in the derivation of the capital benchmarks, instead of end-of-year 1984 current-cost of gross plant. The book value of gross plant is multiplied by the Economic Value/ Book Value

Adjustment Factor in order to derive the benchmark. Fourth, the simplified TFP method uses three-year moving averages of the cost of capital and capital gains in the rental price equation. Fifth, since some of the asset classes have the same BEA price indexes and depreciation rates, it is possible to simplify the computational procedures by consolidating those accounts. This consolidation does not affect the computed values or quantities of capital input and, therefore, does not affect measured TFP. Buildings and cable and wire are consolidated into structures. Switching, transmission, and information origination/termination equipment are consolidated into communications equipment. General support equipment is not affected by this consolidation.

Labor. The simplified TFP method bases the quantity of labor input on the number of employees, reported in the Form M, instead of an index of management and non-management hours worked.

Materials. There is no difference in the way materials input is computed in the original TFP study and the simplified TFP method.

Results of the Simplified TFP Method

Table 8 compares the results from the original Christensen LEC TFP study with the results from the simplified method based on the sample of nine price cap companies included in our original study--Ameritech, Bell Atlantic, BellSouth, GTE, Nynex, Pacific Telesis, Southern New England,

Southwestern Bell, and US West. Table 8 shows the annual rates of growth in total output, total input, and TFP. In the original model, LEC TFP was found to grow at an average rate of 2.4 percent per year over the 1984-1993 period and 2.8 percent per year over the 1988-1993 period. Using the original nine companies, the simplified method results in average TFP growth of 2.9 percent per year over the 1984-1993 period and 3.0 percent per year over the 1988-1993 period.

Table 8
Comparison of LEC TFP Growth for Nine Companies in Original Christensen
LEC TFP Study:
Original Results Versus Simplified Method
1984-1993

<u>Year</u>	<u>Total Output Original</u>	<u>Total Output Simplified</u>	<u>Total Input Original</u>	<u>Total Input Simplified</u>	<u>TFP Growth Original</u>	<u>TFP Growth Simplified</u>
1984						
1985	2.4%	2.8%	1.3%	0.6%	1.1%	2.2%
1986	3.0%	3.1%	0.2%	0.8%	2.8%	2.3%
1987	3.7%	3.8%	1.9%	1.1%	1.8%	2.7%
1988	5.2%	5.5%	3.1%	2.0%	2.1%	3.5%
1989	4.8%	4.6%	2.7%	2.8%	2.0%	1.8%
1990	3.7%	4.1%	-0.9%	-0.2%	4.6%	4.3%
1991	2.3%	2.4%	1.1%	0.6%	1.2%	1.8%
1992	1.9%	2.3%	-1.6%	-0.9%	3.5%	3.2%
1993	3.6%	4.2%	1.0%	0.1%	2.6%	4.1%
Average Growth						
1984-93	3.4%	3.6%	1.0%	0.8%	2.4%	2.9%
1988-93	3.3%	3.5%	0.5%	0.5%	2.8%	3.0%

Table 9 shows results for 1988 through 1994 with Lincoln and Sprint added to the sample. The starting year for the simplified study with the

expanded sample of companies is 1988 rather than 1984 to eliminate adjustments required to 1984-1987 data because of the Uniform System of Accounts Rewrite (USOAR) that took effect in 1988. The expanded sample also contains results for 1994. Using the expanded sample of companies, the simplified method produces average annual TFP growth of 2.9 percent over the 1988-1993 period.. Over this same period, U.S. economy TFP growth averaged 0.1 percent per year, resulting in a TFP growth differential between the LECs and the U.S. economy of 2.8 percent for the 1988-1993 period. For the 1989-1994 period, LEC TFP growth averaged 3.1 percent per year, U.S. TFP growth averaged 0.3 percent per year, resulting in a TFP growth differential of 2.8 percent.

Table 9
LEC TFP Using the Simplified Method
Results for Expanded Sample of Eleven Price Cap Companies
1988-1994

<u>Year</u>	<u>Total Output Growth</u>	<u>Total Input Growth</u>	<u>TFP Growth</u>
1988			
1989	4.7%	2.9%	1.8%
1990	3.8%	0.0%	3.8%
1991	2.7%	0.7%	2.0%
1992	2.0%	-1.5%	3.5%
1993	4.0%	0.3%	3.7%
1994	3.8%	1.4%	2.4%
Average Growth			
1988-93	3.5%	0.5%	2.9%
1989-94	3.3%	0.2%	3.1%

Christensen Appendix 1 A Comparison of BLS and Christensen Total Factor Productivity Methods²³

BLS and Christensen compute total factor productivity as the ratio of total output to total input. Total output includes all services provided by the telephone local exchange carriers: local service, long distance service, intrastate access service, interstate access service, and miscellaneous services. Total input includes all inputs used by the local exchange carriers: capital (plant and equipment), labor, and materials, rents, and services (hereafter referred to as materials).

BLS and Christensen compute total output using economic indexing techniques. The economic indexing technique involves computing quantity indexes for each of the services provided by the local exchange carriers. The quantity index for each of the services is computed by dividing revenue by a price index for that service. The economic indexing technique then "aggregates" these quantity indexes to an index of total output. The total output index is obtained by computing a weighted average of the growth rates for each service, where the weights are based on revenue shares.

BLS and Christensen, compute total input using economic indexing techniques. Quantity indexes are computed for capital, labor and materials. The economic indexing technique then aggregates these

²³ BLS methods are described in: U.S. Department Bulletin of Labor, Bureau of Labor Statistics, Trends in Multifactor Productivity, 1948-81, Bulletin 2178, September 1983; U.S. Department of Labor, Bureau of Labor Statistics, "Multifactor Productivity Measures, 1991 and 1992," USDL 94-327, July 11, 1994; and U.S. Department of Labor, Bureau of Labor Statistics, Labor Composition and U.S. Productivity Growth, 1948-90, Bulletin 2426, December 1993.

quantity indexes to an index of total input. The total input index is obtained by computing a weighted average of the growth rates for capital, labor, and materials, where weights are based on cost shares.

BLS and Christensen compute the quantity index of capital and capital cost in similar ways. Both BLS and Christensen compute the quantity of capital using the "perpetual inventory method." The perpetual inventory method bases the quantity of capital on the cost of plant and equipment added in previous years, adjusted for changes in the prices paid for plant and equipment over time and declines in efficiency of plant and equipment as it ages. BLS and Christensen compute capital cost using a "rental price equation." The rental price equation bases capital cost on taxes, economic depreciation, capital gains, and the cost of capital.

BLS and Christensen compute the quantity index of labor and labor cost in similar ways. The quantity index of labor is based on direct measures such as employees or hours worked. Labor cost is based on wages, salaries, and benefits paid to employees.

BLS and Christensen compute the quantity index of materials and materials cost in similar ways. Materials costs are based on company expenditures for these items. The materials quantity index is calculated by dividing cost by a price index for those services.

Christensen Appendix 2 Construction of Price Indexes for Local, Long Distance, and Intrastate Access Services

The formula used to compute price indexes for local, long distance, and intrastate access services is an approximation to the chain-linked Paasche price index. The chain-linked Paasche price index has the form:

$$\frac{P_t}{P_{t-1}} = \frac{\sum_j P_{jt} \cdot Q_{jt}}{\sum_j P_{j,t-1} \cdot Q_{jt}} \quad (1)$$

where P_{jt} is the price of service j in time period t and Q_{jt} is the quantity of that service provided. Diewert has shown that the chain-linked Paasche price index provides results that are quite similar to those obtained using superlative price indexes and that the chain-linked Paasche price index is superior to the fixed weight Paasche and Laspeyres price indexes.²⁴

The computational procedure relies on the information on rate changes found in the Form M. The Form M reports the estimated change in revenue resulting from the rate changes. The change in revenue is obtained by pricing out a reference volume of service at the old and new rates, or:

$$A_t = \sum_j (P_{jt} - P_{j,t-1}) \cdot Q_j \quad (2)$$

where Q_j is the reference volume for service j . The basic formula used in constructing the local, long distance, and intrastate access price indexes is:

²⁴ W.E. Diewert, "Superlative Index Numbers and Consistency in Aggregation," *Econometrica*, Vol. 46, No. 4, July 1978, pp. 884-900.

$$\frac{P_t}{P_{t-1}} = \frac{\sum_i P_{jt} \cdot Q_{jt}}{\sum_i P_{jt} \cdot Q_{jt} - A_t} \quad (3)$$

$$= \frac{R_t}{R_t - A_t}$$

where R_t is total revenue in year t . If $\sum_i (P_{jt} - P_{j,t-1}) \cdot Q_{jt}$ equals

$\sum_i (P_{jt} - P_{j,t-1}) \cdot Q_{jt}$ then equation (3) is equivalent to equation (1).

The reference volumes used to calculate the revenue impact of rate changes are generally forecasted volumes, and will not necessarily equal actual volumes. Let the revenue change calculated from the actual volume level instead of the reference volume level be equal to $(1 + \epsilon) \cdot A$. The percentage difference in the price index derived from equation (3) and the chain-linked Paasche price index is given by the formula:

$$\ln \left(1 - \frac{\epsilon \cdot A_t}{R_t - A_t} \right)$$

If, for example, total revenue in year t is \$1 billion, the calculated change in revenue due to rate changes in that year is \$30 million (three percent of total revenue), and if ϵ equals .05 (that is the change in revenue from rate changes, when calculated at actual volume levels, is \$31.5 million), then the percentage difference between the chain-linked Paasche price index and the index derived from (3) is -.15%. If ϵ equals -.05, then the difference is +.15%.

Calculating the Price Index When Rates are Implemented Mid-Year.

The calculated change in revenue due to rate changes is reported on an annual basis. In other words, it reflects the impact on revenue for the

twelve month period following the rate change. If the rate change occurs at the beginning of the year, the full impact of the rate change will be seen in that year. If the rate change occurs mid-year, however, part of the impact will be observed during the current year, with the remainder of the impact being observed in the following year. This implies that the index formula in equation (3) must be generalized to account for mid-year rate changes. In the generalized version of (3), A is replaced by the impact of current year rate changes on current year revenue plus the impact of previous year rate changes on current year revenue. The generalized formula is:

$$\frac{P_t}{P_{t-1}} = \frac{R_t}{R_t - E_t - F_t} \quad (4)$$

where E is the impact of current year rate changes on current year revenue and F is the impact of previous year rate changes on current year revenue (the carryover of previous year rate changes). The carryover of previous year rate changes is equal to the difference between A and E for the previous year, multiplied by the growth in total revenue between the previous year and the current year (in order to incorporate the impact of volume growth on the magnitude of the rate changes).

$$\frac{P_t}{P_{t-1}} = \frac{R_t}{R_t - E_t - (A_{t-1} - E_{t-1}) \cdot \frac{R_t}{R_{t-1}}} \quad (5)$$

Adjusting the Price Index for Net Credits. Finally, an adjustment must be made to the price index in order to account for any net credits paid from the LEC to its customers. If we define B_t to be revenue before net credits, then B_t is equal to

$$\sum_i (P_{it} - P_{i,t-1}) \cdot Q_{it} = P_t \cdot Q_t$$

where Q_t is the aggregate quantity index of telephone services. In order to calculate the quantity index Q_t from booked revenue after credits, one must adjust equation (5):

$$\frac{P_t}{P_{t-1}} = \frac{P_t}{P_{t-1}} \cdot \frac{R_t / (R_t - C_t)}{R_{t-1} / (R_{t-1} - C_{t-1})}$$

$$= \frac{R_t}{R_t - E_t - (A_{t-1} - E_{t-1}) \cdot \frac{R_t}{R_{t-1}}} \cdot \frac{R_t / (R_t - C_t)}{R_{t-1} / (R_{t-1} - C_{t-1})}$$

where C_t is net credits in year t . This is the formula actually used to compute local, long distance, and intrastate access price indexes. Below we provide a numerical example of this computation.

Exhibit A-1 provides sample calculations for both a rate increase. Revenue is \$9,100 in year $t-1$ and \$10,000 in year t . The year t rate increase occurs on July 1; the annual revenue change is \$400. In year $t-1$ there was a rate change on June 5, with an annual revenue impact of \$400. Since the year t rate change occurs halfway through the year, its impact on year t revenue is \$200 ($0.5 \cdot \400). The remaining \$200 of the year t rate change will become a carryover in year $t+1$. The rate change in year $t-1$ was effective for 57.5% of that year, producing a \$230 (i.e., $0.575 \cdot \$400$) revenue impact in year $t-1$. This leaves a carryover of \$186.81 ($= (\$400 - \$230) \cdot (\$10,000 / \$9,100)$) to be accounted for in year t . (Net credits in both $t-1$ and t are assumed to be \$300.)

Once the change in price level is computed for each year of the study, an index of annual rate levels can be computed by initializing the index at 1.0 in the chosen base year. The index level for each subsequent

year is based on the percentage change in the price level for that year over the previous year.

Table A2.1
SAMPLE RATE INDEX CALCULATION

(a) Revenue for year t, R(t)	\$10,000.00
(b) Revenue for year t-1, R(t-1)	\$9,100.00
(c) R(t)/R(t-1)	1.0989
(d) Rate change in year t-1, A(t-1)	\$400.00
(e) Date of year t-1 rate change	June 5
(f) Effective in year t-1 revenue, E(t-1) (.575·d)	\$230.00
(g) Carryover in year t, ((d - e)·c)	\$186.81
(h) Rate change in year t, A(t)	\$400.00
(l) Date of year t rate change	July 1
(j) Effective in year t revenue, E(t) (.5·h)	\$200.00
(k) Year t revenue net of rate changes (a - g - j)	\$9,613.19
(l) Year t-1 credits, C(t-1)	\$300.00
(m) Year t credits, C(t)	\$300.00
(n) Adjustment for net credits (a/(a-m))/(b/(b-l))	.9969
(o) Change in price index ((a)/(k)·(n))	1.0371

**Christensen Appendix 3
Response to Appendix F:
The Appropriate Data Set to Use in
Analyzing Telephone Industry Input Prices**

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December 18, 1995

In Appendix F of the FCC's First Report and Order in CC Docket No. 94-1, FCC staff members, C. Anthony Bush and Mark Uretsky consider whether short-run or long run input price data should be used to forecast the future trend in input prices.²⁵ They tentatively concluded that the short-term input price growth differential measured over the post-divestiture period, 1984-1992, represented a structural shift in the input price differential and should be used to forecast future input prices for the purposes of setting a price cap X factor. However, they do not fully consider the evidence placed on the record.

In particular, they do not fully evaluate a USTA ex parte placed on the record on February 1, 1995 in which Dr. Laurits R. Christensen demonstrates that there is no statistical validity to the claim that there has been a structural change in the relationship between telephone industry and U.S. economy input prices (hereafter referred to as the "Christensen input

²⁵ C. Anthony Bush and Mark Uretsky, "Input Prices and Total Factor Productivity," In the Matter of Price Cap Performance Review for Local Exchange Carriers, First Report and Order, CC Docket 94-1, FCC 95-132 (March 30, 1995), Appendix F.

price affidavit").²⁶ Bush and Uretsky stated that the Christensen input price affidavit was not given full consideration because of differences in the input price data series used in the affidavit and input price data used by NERA in this proceeding:²⁷

Christensen's time-series is completely different from NERA's, although both are based on data from various studies by Christensen. Christensen has provided no justification for using a different version of the LEC input price series for the period 1960-1984 than NERA's version. Further, Christensen provides no justification for using a different beginning date for the series than NERA (1949 instead of 1960). Because of these discrepancies, we cannot accept Christensen's conclusion that the input price differential is zero.

"Christensen" versus "NERA" data. As explained in the Christensen input price affidavit, the data used in the affidavit come primarily from the study of the Bell System total factor productivity and the USTA LEC study, both performed by Dr. Christensen. The Bell System study covers the 1949-1979 period, and the USTA LEC study covers the 1984-1992 period. The 1980-1984 period uses data from a Bell Communications Research (Bellcore) report (1980-1982) and the study relied upon by NERA (1983-1984).²⁸ The methods used in the Bell System and Bellcore studies are the

²⁶ "An Input Price Adjustment Would Be an Inappropriate Addition to the LEC Price Cap Formula," Affidavit of Dr. Laurits R. Christensen filed on behalf of the United States Telephone Association, CC Docket 94-1, February 1, 1995.

²⁷ Bush and Uretsky, p. 13.

²⁸ In particular, telephone industry input prices come from the Bell System study for the 1948-1979 period and the USTA LEC study for the 1984-1992 period. Telephone industry data for the 1980-1982 period come from Bell Communications Special Report SR-FAD-000552 (May 1987); and, for the 1983-1984 period, L.R. Christensen "Total Factor Productivity Growth in the U.S. Telecommunications Industry and the U.S. Economy, 1951-1987," Schedule 3 to Direct Testimony, Case No. PU-2320-90-149, North Dakota Public Service Commission, 1990.

same as those employed in the Christensen LEC study for USTA. As described below, the study relied upon by NERA employs some simplifications relative to the other three studies, making its input price results not directly comparable to the other three studies. However, it is the only data set available for the 1983-1984 period. Minimizing its use to only two years and relying on the Bell System, Bellcore, and USTA studies for the vast majority of the observations provides the most theoretically consistent telephone input price time series available.²⁹

It is important to understand that the Christensen data used by NERA for the pre-1984 period come from a study conducted by Dr. Christensen in connection with his 1990 testimony for U.S. West in North Dakota.³⁰ The study filed in North Dakota was designed to approximate Dr. Christensen's more in-depth TFP studies. Unlike his other more detailed studies of the telephone industry, this study relied on aggregate telecommunications industry data from Bureau of Economic Analysis (BEA) publications (hereafter, this study is referred to as the "telecommunications industry" study).

One of the major differences between the telecommunications industry study filed in North Dakota and the more comprehensive studies, such as the LEC study for USTA and the Bell System study, is the

²⁹ In a March 21, 1995 ex parte, USTA explained the sources of the U.S. input price numbers and why they may differ between the "Christensen" and "NERA" data sets.

³⁰ Direct Testimony of Laurits R. Christensen, North Dakota Public Service Commission Case No. PU-2320-90-149, October 1, 1990, Schedule 3.

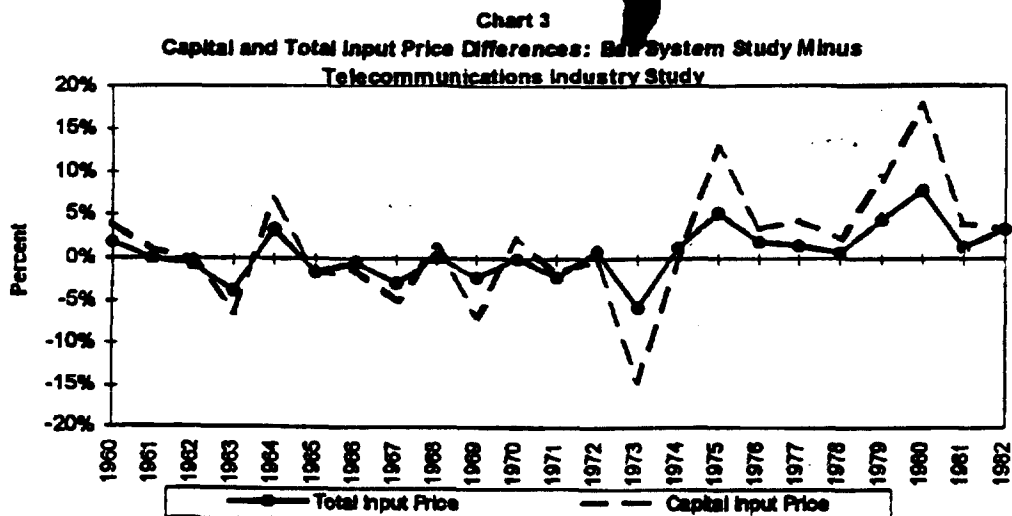
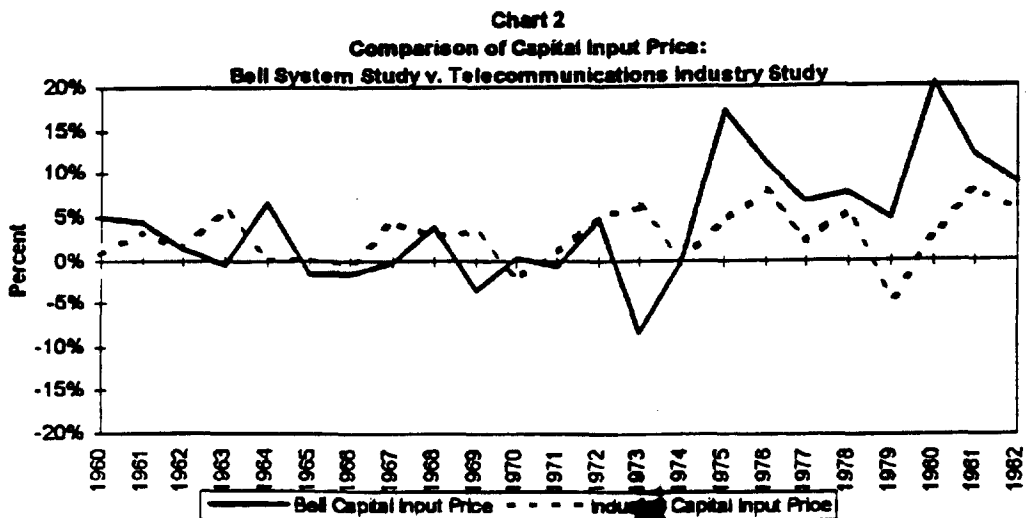
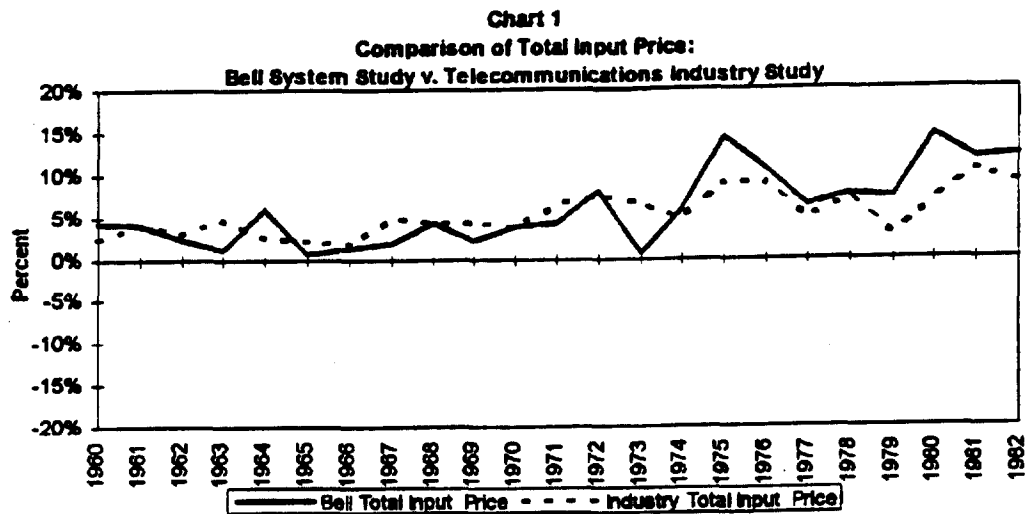
measurement of capital. The telecommunications industry study does not measure the value of capital with the Christensen-Jorgensen methodology as the other studies do, but measures it as the residual of gross national product originating in the telecommunications industry less labor compensation in the telecommunications industry. In effect, this measures the value of capital as revenue less labor and materials cost. Therefore, when the telecommunications industry study filed in North Dakota is used for the pre-1984 period and the USTA LEC study is used for the post-1984 period, there is a notable lack of correspondence between the methods used to measure capital input prices for the pre-1984 and post-1984 periods.³¹ This mismatch creates an artificial difference in observed pre- and post-1984 input prices.

This mismatch has a minimal impact on TFP results. However, the telecommunications industry study data set does not exhibit the same pattern of input price growth, particularly with respect to capital, as the Bell System input price data set. Specifically, the telecommunications industry study data set does not fully reflect the large increases in capital input prices in the late 1970's and early 1980's when interest rates were rising. This is illustrated in Charts 1 through 3, which compare the input price data from the Bell System and Bellcore studies to the telecommunications

³¹ The "NERA data" cited by Bush and Uretsky in Appendix F used the simplified study for the pre-1984 period and the Christensen LEC study commissioned by the USTA for the post-1984 period.

industry study for the 1959 to 1982 period.³² Chart 1 shows the growth in total input price for the two data sets between 1959 and 1982. Total telephone input price grew at an annual average rate of 5.8 percent in the Bell System/Belcore data and 5.2 percent in the telecommunications industry study data. Chart 1 illustrates that the price of total input was much more volatile in the Bell System and Belcore data. The standard deviation of total input price growth over the 1959-1982 period was .0423 in the Bell System/Belcore data versus .0241 in the telecommunications industry study data. Chart 2 shows that this was primarily due to the changes in capital input prices in the Bell System/Belcore data relative to the telecommunications industry study data. Capital input price grew at an annual average of 4.3 percent in the Bell System/Belcore data and 2.8 percent in the telecommunications industry study data. The Bell System/Belcore capital input price data was also much more volatile, with a standard deviation of .0654 versus .0305 for the telecommunications industry study data. Chart 3 illustrates that the difference in overall input price growth between the Bell System/Belcore data and telecommunications industry study data are clearly driven by the differences in capital input price growth.

³² The first observed growth rate for the 1959 to 1982 period occurs in 1960--i.e., the growth in 1960 over 1959. Therefore, the first data point in Charts 4 and 5 is 1960.



In summary, the long-term input price data series found in the Christensen input price affidavit, comprised primarily of results from Christensen's Bell System study and Christensen's USTA LEC study, represents the most methodologically consistent series over time. This data series is clearly superior to the one that uses the telecommunications industry study for the pre-1984 period. Moreover, any statistical analysis using the series with the telecommunications industry study data will produce results that show differences in the pre- and post-1984 input price relationships simply due to the different methodologies used to generate the pre- and post-1984 input price series. The Bell System/USTA LEC data series represents the most consistent series and, therefore, it is the most appropriate for testing the input price differential. It also means that the Christensen input price affidavit cannot be dismissed on the grounds that it uses different and, supposedly, inferior data: full weight needs to be given to the Christensen input price affidavit in considering whether the X factor should include an input price differential.

Christensen Input Price Affidavit. Given that the 1949-1992 data used in the Christensen input price affidavit represents the most consistent series over time, it is important to restate the major findings of the affidavit. The February 1, 1995 affidavit concluded that, over the 1948 to 1992 period, input prices for the U.S. economy and the telephone industry grew at the essentially same rate. Over this period, input prices grew at an average annual rate of 4.75 percent for the U.S. economy and 4.70 percent for telephone